CHANGES IN SUCROSE SYNTHETASE AND SUCROSE PHOSPHATE SYNTHETASE ACTIVITIES DURING STORAGE OF POTATOES[1]

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ABSTRACT

Sucrose synthetase in potatoes decreased sharply after harvest and remained low during warm storage. The activity increased slowly when the tubers were placed in cold storage and continued to increase after 30 weeks. Sucrose phosphate synthetase also decreased in warm-stored Norchip tubers, but it increased in Kennebec tubers. It increased quite rapidly in both varieties during the first few weeks of cold storage and then essentially leveled off. Both enzymes decreased during reconditioning of cold-stored tubers, but they tended to increase in Kennebec potatoes after prolonged reconditioning. Sucrose phosphate synthetase was much higher than sucrose synthetase in all stored tubers.

RESUMEN

"Sucrose synthetase" en papas disminuyó severamente después de la cosecha y continuó a bajo nivel durante al almacenaje a temperatura más o menos caliente. La actividad se incrementó lentamente cuando los tubérculos fueron colocados en un almacén frío y continuó incrementándose después de 30 semanas. "Sucrose phosphate synthetase" disminuyó también en tubérculos de la variedad Norchip almacenados bajo temperaturas calientes, pero en cambio aumentó en tubérculos de la variedad Kennebec. Esta aumentó rápidamente en ambas variedades durante las primeras dos semanas de almacenaje frío y después se nivelaron. Ambas enzimas disminuyeron durante el reacondicionamiento de los tubérculos almacenados en lugares fríos, y tendieron a aumentar en las papas Kennebec después de un prolongado reacondicionamiento.

"Sucrose phosphate synthetase" fue mucho más elevada que "sucrose synthetase" en todos los tubérculos almacenados.

Sucrose is one of the major sugars in cold-stored potatoes. It is also an intermediate in the pathway for glucose and fructose accumulation. The hydrolysis of sucrose in the tuber is catalyzed by invertase and is regulated by fluctuation in the level of enzyme relative to the level of a proteineous invertase inhibitor (Pressey and Shaw 5). Sugar accumulation is usually accompanied by an excess of invertase, whereas excess invertase inhibitor is associated with constant or decreasing sugar levels. However, I have encountered samples which were not accumulating sugars despite high excesses of invertase (Pressey 4). This points to the possibility

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that the availability of sucrose at the site of invertase action may be a controlling factor in the accumulation of reducing sugars.

Two pathways for sucrose synthesis, involving the enzymes sucrose synthetase and sucrose phosphate synthetase, respectively, have been identified in potatoes (Schwimmer and Rorem 6, Slabnik et al 7). It is not known whether both pathways participate in sucrose formation in cold-stored tubers. This study was undertaken to determine if the activities of sucrose and sucrose phosphate synthetases vary in potatoes during storage, and if any changes are related to sugar accumulation.

Materials and Methods

Kennebec and Norchip potatoes were grown in 1968 on the Research Farm of the Red River Valley Potato Growers' Association, Grand Forks, North Dakota. The tubers were harvested on September 11 and cured at 65 F for 10 days. Most of the tubers were then transferred to 40 F but some were left at 65 F.

The sugars, sucrose synthetase, and sucrose phosphate synthetase were measured as described earlier (Pressey 3). Sucrose synthetase was determined only by the sucrose synthesis method.

Results

Changes during warm storage. The sucrose synthetase activity at harvest was about 3.5 units/mg protein in both Norchip and Kennebec tubers (Fig. 1). The activity decreased sharply in the harvested tubers to only about 0.05 units/mg protein after 10 days in the curing room and then remained low over a 2 month period. Sucrose phosphate synthetase activity was much lower than the sucrose synthetase activity at harvest. It also decreased in Norchip tubers, but it increased 2-fold during the first month in Kennebec tubers (Fig. 1). In both varieties, total sugars decreased after harvest. The level of reducing sugars remained low in Norchip and increased slightly in Kennebec.

Changes during cold storage. Sucrose synthetase began to increase slowly after the cured tubers were placed in storage at 40 F. (Fig. 2). The greater increase in activity occurred in Norchip tubers. The activity was still increasing after 31 weeks, but the level was less than a tenth that at harvest. Sucrose phosphate synthetase increased quite rapidly during the first weeks of cold storage. It then leveled off in the variety Norchip, but continued to increase slowly in Kennebec tubers. Sucrose phosphate synthetase was always higher than sucrose synthetase in cold-stored potatoes.

The sugars increased sharply during the first 4 or 5 weeks of cold storage (Fig. 2). They attained maximum levels shortly after this period and then decreased very slowly on continued cold-storage. As in previous years, Kennebec accumulated more reducing sugars than Norchip. Both varieties accumulated higher levels of sugars than I have observed during the previous 3 years. Total sugars were especially high in Norchip tubers. On the basis that sucrose accounts for the difference between total and reducing sugars, it constituted about half of the soluble sugars in Norchip. The amount of sucrose in Kennebec was considerably lower.

Changes during reconditioning. After 8 weeks of cold storage, samples of potatoes were transferred to 65 F, and the changes in sugars, sucrose

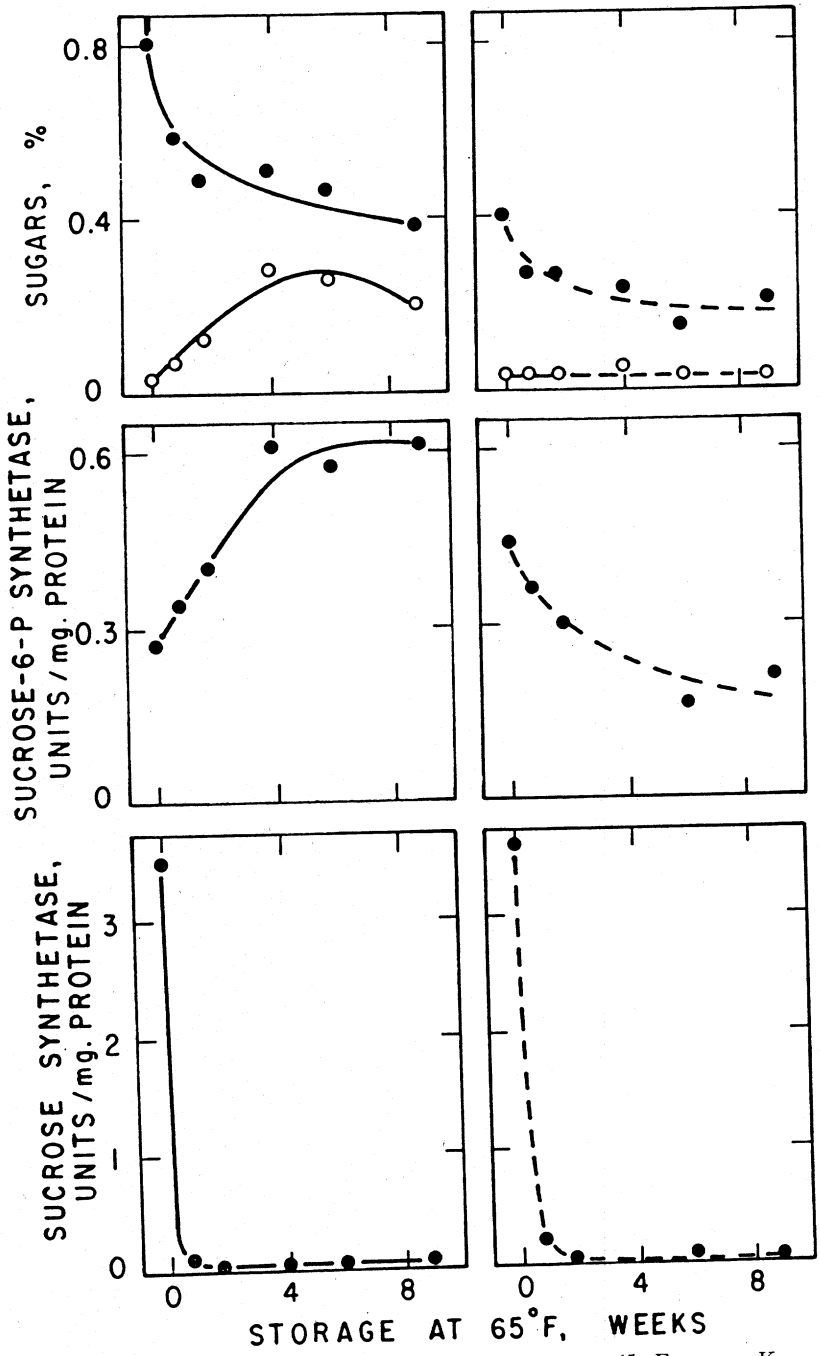

FIG. 1.—Changes in tuber composition during storage at 65 F. ——, Kennebec variety; - - - -, Norchip variety; ●, total sugars; ○, reducing sugars.

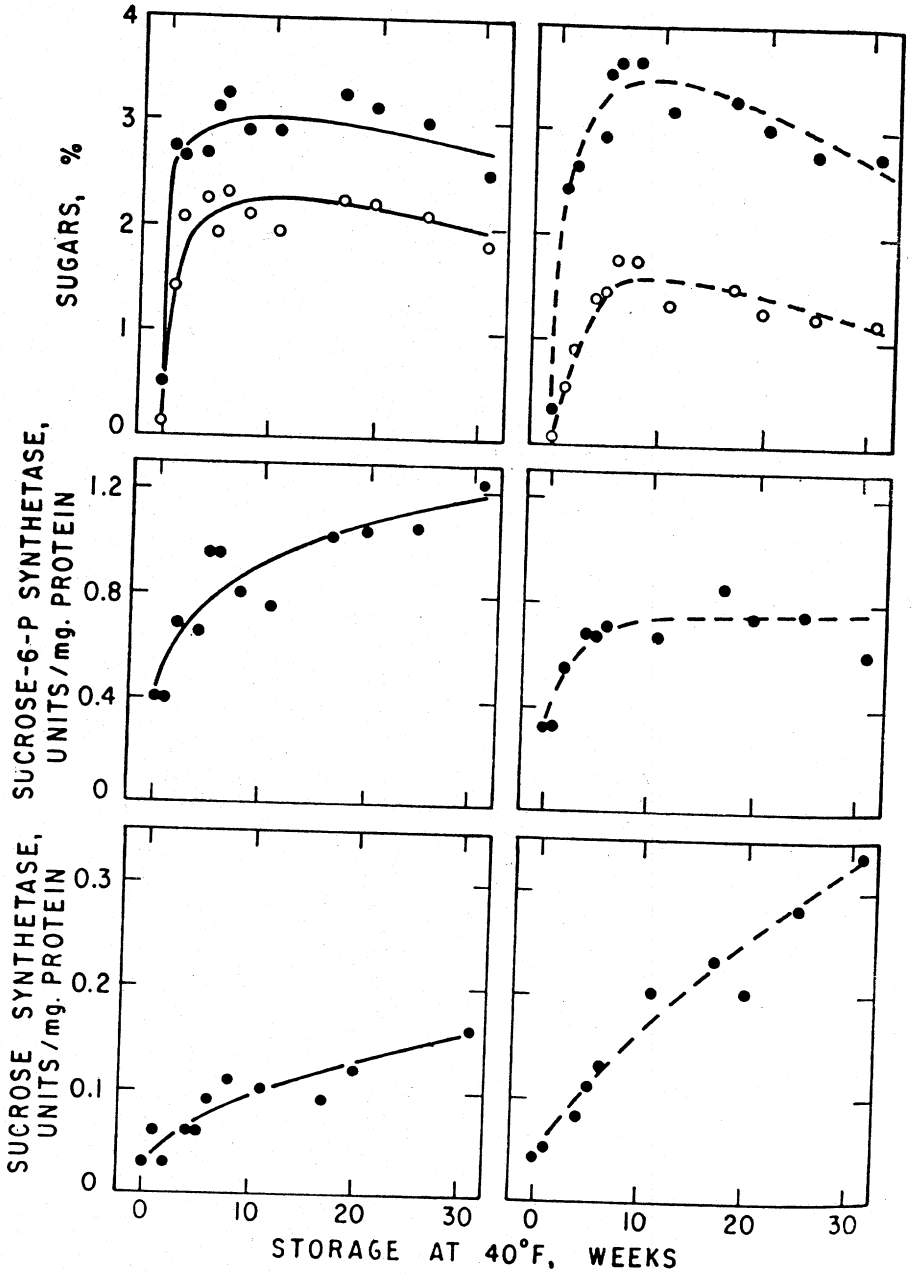

FIG. 2.—Changes in tuber composition during storage at 40 F. ——, Kennebec variety; - - - -, Norchip variety; ●, total sugars; ○, reducing sugars.

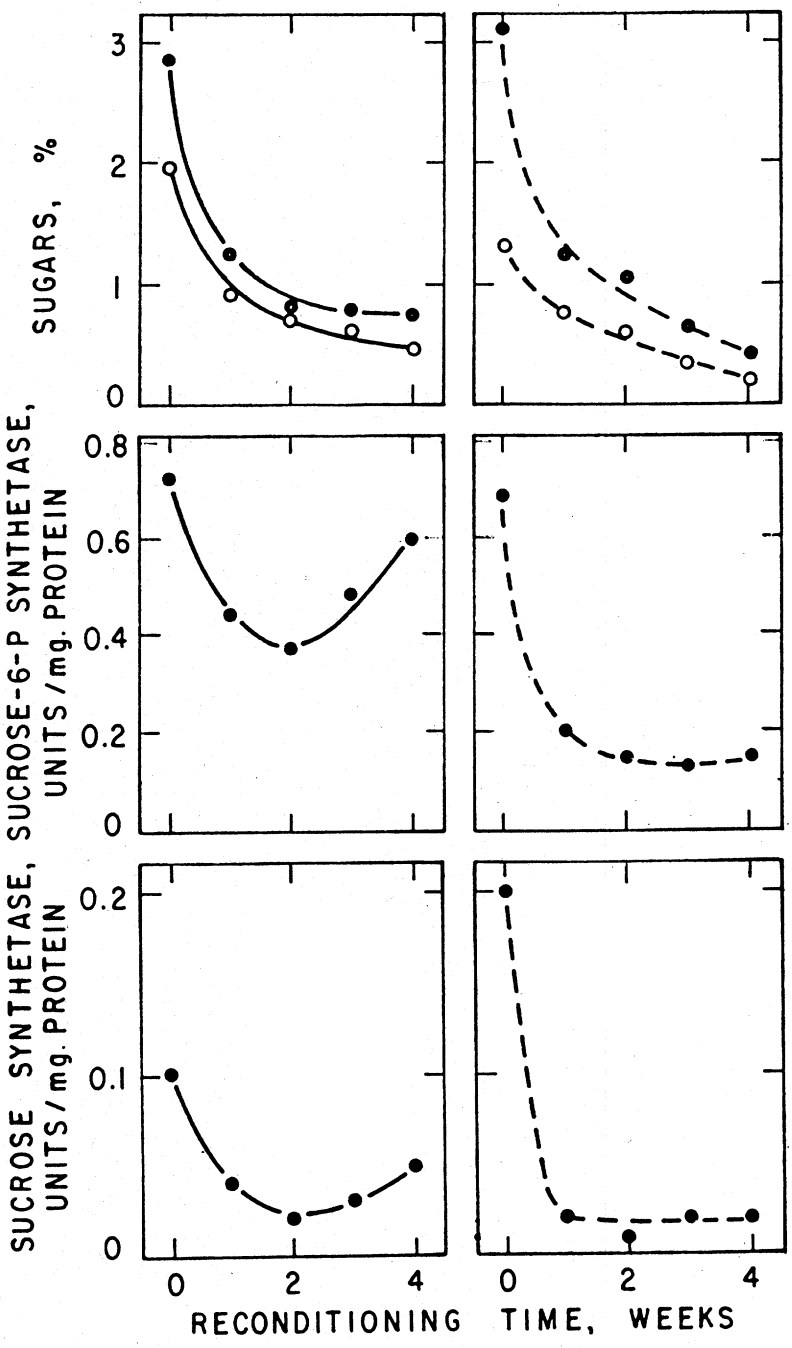

FIG. 3.—Changes in composition during reconditioning of cold-stored potatoes. ——, Kennebec variety; - - - -, Norchip variety; ●, total sugars; ○, reducing sugars.

synthetase, and sucrose phosphate synthetase were studied (Fig. 3). The sugars decreased sharply during the first week of reconditioning and then slowly during the next three weeks. As observed previously, Norchip tubers reconditioned better than Kennebec. The response of Kennebec potatoes to reconditioning was poor and they were unacceptable for chipping even after 4 weeks.

The changes in sucrose and sucrose phosphate synthetases roughly paralleled the changes in sugars initially. Both enzymes decreased markedly after the potatoes were placed at 65 F. The activities remained low in Norchip tubers, but they began to increase after the second week in Kennebec. As in cold-stored tubers, sucrose phosphate synthetase was the major enzyme in both varieties after reconditioning.

Discussion

The existence of two pathways for sucrose biosynthesis in potato tubers implies specialized functions for each. The sucrose synthetase reaction is readily reversible (Avigad 1) and there is the possibility that it is involved in cleavage rather than synthesis of sucrose. I had found earlier that this enzyme is present at highest levels in developing tubers (3). The sugars of translocation in the potato have not been identified, but sucrose may be one of the important ones. If it is, the role of sucrose synthetase in the growing tuber could be cleavage of translocated sucrose prior to incorporation into starch.

The activity of sucrose synthetase is much lower in stored than growing tubers. The enzyme responds to changes in storage temperature, although the changes are usually small and occur slowly. It increased during cold storage, but the change in activity did not parallel the formation of sugars. Sugar accumulation was complete within about 4 weeks whereas sucrose synthetase continued to increase even after 30 weeks. In terms of enzyme levels in relation to the sugars, there does not appear to be a connection between sucrose synthetase and sugar accumulation. On the other hand, this enzyme decreases during reconditioning, suggesting that it may be involved in the metabolism of cold-stored potatoes.

In contrast to the reversibility of sucrose synthetase, sucrose phosphate synthetase functions only in the synthetic direction (Mendicino 2). This enzyme is present at very low levels in young tubers but gradually increases during maturation (3). It decreased slightly in warm-stored Norchip tubers which did not accumulate sugars. However, it increased 2-fold in warm-stored Kennebec tubers which accumulated a low level of sugars. The activity increased in both varieties during cold storage, with the higher activity in Kennebec. The changes in sucrose phosphate synthetase match the accumulation of sugars much better than do the changes in sucrose synthetase. Sucrose phosphate synthetase also substantially exceeds sucrose synthetase in stored potatoes regardless of storage temperature and duration. The results, therefore, indicate that sucrose phosphate synthetase rather than sucrose synthetase may be the enzyme responsible for sucrose formation in cold-stored potatoes.

Acknowledgment

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Literature Cited

1. Avigad, G. 1964. Sucrose-uridine diphosphate glucosyl-transferase from Jerusalem artichoke tubers. J. Biol. Chem. 239: 3613-18.
2. Mendicino, J. 1960. Sucrose phosphate synthesis in wheat germ and green leaves. J. Biol. Chem. 235: 3347-3352.
3. Pressey, R. 1969. Potato sucrose synthetase: Purification, properties, and changes in activity associated with maturation. Plant Physiol. 44: 759-764.
4. Pressey, R. 1969. Role of invertase in the accumulation of sugars in cold-stored potatoes. Amer. Potato J. 46: 291-297.
5. Pressey, R. and R. Shaw. 1966. Effect of temperature on invertase, invertase inhibitor, and sugars in potato tubers. Plant Physiol. 41: 1657-61.
6. Schwimmer, S. and E. S. Rorem. 1960. Biosynthesis of sucrose by preparations from potatoes stored in the cold and at room temperature. Nature 187: 1113-14.
7. Slabnik, E., R. B. Frydman, and C. E. Cardini. 1968. Some properties of potato tuber UDPG:D-fructose-2-glucosyltransferase (E.C. 2.4.1.14) and UDPG:D-fructose-6-phosphate-2-glucosyltransferase (E.C. 2.4.1.13). Plant Physiol. 43: 1063-68.